Can Climate Smart Forages Replace Concentrates in Dairy Milk Production?

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Abstract

The contribution of the dairy sector to the GDP, and household nutrition in Kenya cannot be overemphasised. However, competitiveness and growth of the sector has largely been impeded by issues relating to access to quality feed in sufficient quantities due to the effects of climate change. Consequently, the use of concentrates has been rampant, but their availability and quality are highly variable and costs are prohibitive for most resource constrained farmers. Therefore, use of high-quality nutritive forages such as lucerne, pearl millet, sugar graze sorghum and forage maize to mitigate against these fluctuations in basal feed is a pliable pathway that would reduce the need for concentrates.

Cross-sectional data on farm and farmer characteristics and factors of production collected from 410 small-scale dairy farmers sampled from Kericho, Nakuru and Uasin Gishu counties were used to estimate Stochastic Production Frontier simultaneously with a technical inefficiency model; while Tobit regression model was used to assess the factors associated with technical inefficiency. The empirical results indicated that the dairy farmers had a mean of 63.27 % technical efficiency, in addition the frontier exhibited increasing returns to scale and that farm technical inefficiencies are positively related to the quantities of concentrates, dairy production system and farming experience. Improving farmers access to key agricultural resources would increase the local availability of reliable climate-resilient forage for dairy cattle, and ensure all year-round quality feed supply. This would reduce the need of concentrates thus improving dairy productivity while reducing the costs of production.

1. **Introduction**

Agriculture is the mainstay of the Kenyan economy and contributes about 26% to the gross domestic product (GDP). The sector is a source of employment to about 75% of the rural folk, contributes to human nutrition and livelihoods (Food and Agriculture Organization FAO, Kenya at a glance; Omondi *et al*., 2017). Livestock sector contributes 40% of the agricultural GDP with the dairy sector contributing 3.5-4.5% of the GDP (Kemboi *et al*., 2020).

The dairy sector is dominated by over 1.8 million smallholder farmers who own 1-3 cows, and this makes up more than 80% of the national herd (4.2 -6.7 million cattle) (International Livestock Research Institute - ILRI, 2019). Kenya has the highest per capita milk consumption in sub-Saharan Africa (110 litters) and an annual total production of 5.2 billion litres; 70% of which is sold raw to consumers through informal market channels (Ssekibaala, 2019).

Despite the enormous potential, the dairy sector is not competitive and growth has been impeded by issues relating to production and productivity, reliability and quality of markets, access to quality feed and fodder and unresponsive dairy policy frameworks (Rademaker et al 2016). Access to quality feed and fodder is a major constraint that directly impacts on production and productivity of dairy animals because the sector is dependent on rain fed forages. Natural pastures, planted fodder and crop residues supplemented with concentrates are the most commonly used feed resources in the smallholder Kenya dairy production systems (Njarui et al 2016). The quality of natural pastures is often low even during the raining season while the most predominant planted fodder (Napier grass – *Pennisetum purpureum*) has low nutrient content especially crude protein to support high milk production. Quality of crop residues on the other hand (maize stover, straws (wheat, rice, barley), banana stems, sugar cane tops) is generally low and critical for maintenance needs especially during the dry season.

During the rainy season, there is usually a glut in milk production which impacts negatively on price per litre whereas the converse is true during the dry season. In order to increase the supply and quality of dairy products available to families and local communities, there is need to address these seasonal fluctuations in quality and quantity of fodder. This will drive the competitiveness of the Kenyan dairy industry to withstand climate and pandemic-related shocks.

Consequently, the use of concentrates is rampant in an effort to bridge the nutritional gap in the available forages but their availability and quality is highly variable and costs are prohibitive for most resource constrained farmers. Use of climate smart forages, high-quality nutritive forages, is a pliable pathway that would reduce quantity of forage used and need for concentrate feeding. However, this has not been a common practise because farmers undervalue the potential of these forages due to labour constraints, lack of knowledge of the nutrient value of these forages and its' relative costs versus concentrates.

Objectives of the Study

The general objective of this study was to evaluate the technical efficiency of using climate smart forages in dairy production in Kenya.
This study sought to address the following specific objectives:
1. To determine the level of technical efficiency of climate smart forage use among smallholder dairy farmers.
2. To examine the farm and farmer characteristics affecting technical efficiency of climate smart forage use among smallholder dairy farmers.

2. Research methodology

2.1 Study area

The study was conducted in Nakuru, Kericho and Uasin Gishu counties in rift valley Kenya where dairy farmers were being trained on the production and utilization of Climate smart forages in dairy production.

Table 1 Study area characteristics

County	Area km^2	Population (KNBS, 2019)	Location	Rain fall p.a	Temperature mean
Kericho	2,454	901,777	0^{0}22^I 0.0^{II}N 35^0 17^I 60.0 E	2125 mm	18c^0
Nakuru	2955.3	1,163,186	0^{0}31^I 0.0^{II}N 35^0 16^I 59.88 E	2027 mm	24^{0}c
Uasin Gishu	7496.5	2,162,202	0^{0}16^I 59.99^{II}N 36^0 4^I 0.01^0 E	762 mm	17.5^{0}c

2.2 Sampling procedure and sources of data

Multistage sampling technique was used. The first stage targeted dairy farmers within Kericho, Nakuru and Uasin Gishu counties, within a sampling frame of 5000 dairy farmers who had been trained by Kenya Nourishing Prosperity Alliance (KNPA) project at the various adaptive research demonstration sites.

Secondly, the sample size was determined, using the Yamane (1967:886) formula, The sample size of 410 farmers was distributed proportionately among the demonstration sites. Simple random sampling was used to draw respondents around each of the demonstration site.

Primary data collected through field surveys using a structured questionnaire, digitised into Kobo Collect an Open Data Kit to enable electronic data collection. The primary data collected included farmer's and farm characteristics, socio-economic factors, feeds and feeding of livestock, milk production and marketing.

2.3 Data analysis

The Cobb-Douglas stochastic frontier model with distributional assumptions was selected to assess the economic efficiencies of dairy production farms since. Besides its generalized form, it is a simple tool that can be handled easily, even for multiple inputs (Bhanumurthy, 2002). The empirical version of the stochastic frontier model (Berger & Humphrey, 1997) with the specification of Cobb-Douglas functional form can be expressed with the decomposed errors.

The frontier production function;

$$lnYi = \beta o + \beta 1 lnX1i + \beta 2 lnX2i + .. \beta n lnXni + (Vi - Ui) \quad (1)$$

Where; y_i – is the dairy output of i^{th} farm in litters

i – is the i^{th} farm, (i =1, 2. .410)

β – Unknown coefficients of the independent variables to be estimated

X_i – the independent variables (farm size, herd size, labour, forage used)

U_i – farm specific TE

V_i – statistical disturbance term.

The frontier cost function;

$$lnCi = \alpha o + \alpha 1 lnP1i + \alpha 2 lnP2i + \cdots \alpha n lnPni + (Vi - Ui) \quad \mathbf{(2)}$$

Where; C_i – the minimum cost incurred by the i^{th} farm to produce output Y

P_i – a vector of input prices employed by the i^{th} farm in milk production

α- parameters to be estimated.

Using the exponential form of the disturbance term in STATA, the maximum likelihood estimates of the stochastic frontier production function parameters were obtained.

Tobit model

Since efficiencies are not binary but rather bounded between zero and one, the Tobit model was used to the efficiency estimates obtained on some farm-specific attributes.

The Tobit model was specified as follows;

$$Ui = \beta o + \beta 1 X1i + \beta 2 X2i + \cdots \beta n Xni + \varepsilon i \quad (3)$$

Where; X_i – farm-specific attributes (gender, age, occupation, extension services, level of education, experience, off-farm income)

U_i – farm-specific E of the i^{th} dairy farmer (ranges 0 to 1)

ε- Independently distributed error term assumed to be normally distributed with a mean of zero and a constant variance.

3. Results and discussion

3.1 Descriptive statistics of dairy farmers sampled

Table 2 Farmer characteristics

	Frequency	**Percentage (%)**
County		
Kericho	148	36.45
Nakuru	159	39.16
Uasin Gishu	99	24.38
Gender of Household head (HH)		
Female	1=153	37.68
Male	2=253	62.32
Level of education HH		
No formal education	6	1.48
Primary	117	28.82
Secondary	210	51.72
Post-Secondary	73	17.98
Main occupation of HH		
Businessman	17	4.19
Farmer	363	89.41
Formal employment	24	5.93
Others	2	0.5
Main decision maker		
Household head	330	81.28
Joint (HH/spouse)	60	14.78
Spouse	9	2.22
Others	7	1.73
Labour source		
Family	287	70.69
Family & Hired	28	6.9
Hired	91	22.41
	Mean	**S.E**
Respondent age (years)	47.32	12.65
Family size (number)	5.46	
Farming Experience (years)	13.32	10.2

A total of 410 farmers were interviewed from Kericho, Nakuru and Uasin Gishu Counties, translating to 36.45%, 39.16% and 24.38% respectively. The results show that 62.32% of the sampled households were male headed while 37.68% households were female headed. About 51.72% of the respondents attained secondary education while those with no formal education were 6 accounting for 1.48% of the total farmers interviewed. Most farmers (89.41%) engaged in farming as the main occupation where decisions on dairy activities were made by the household heads (81.28%). Family labour was the main source of labour for dairy production accounting for 70.69% of the total labour, 6.90% was hired labour while 22.41% sourced labour from both family and hiring.

The mean age of the respondents was 47.32 years and the mean household size, defined by the number of people who had lived in the household the previous 12 months was 5.46 members. The results show that farmers had engaged in dairy production for about 13 years

3.2 Descriptive statistics of farm

Table 3 Farm characteristics

	Frequency	**Percentage %**
Leased land for fodder production		
Yes	57	14.04
No	349	85.96
Dairy production system		
Free grazing	202	49.75
Semi-intensive	136	33.5
Zero grazing	68	16.75
Feed Source		
Purchased	25	8.94
On-farm	331	81.53
On-farm & purchased	50	10.1
	Mean	**SE**
Land under dairy production (Ha)	0.99	1.39
Total Cows (numbers)	4.69	5.5
Daily milk production (litres/herd)	19.43	34.8

Minority (14.04%) leased land for fodder production. The dairy production systems adopted by the farmers varied from free grazing, semi-intensive to zero grazing with proportions of 49.75%, 33.5% and 16.75% respectively. The majority of the farmers produced their own forages (81.53%) which was supplemented with purchased fodder during periods of scarcity (10%). The average land size under dairy production was 0.99 hectares. The mean number of cows (heifers, lactating and dry cows) in the households surveyed was 4.69 cows with an average daily milk production per herd of 19.46 litres.

3.3 Technical efficiency estimation

The sum of estimates for the coefficients in the estimated model was 0.9912 which implies on average, the production frontier exhibited increasing returns to scale. In other words, if all the inputs are increased by 1 %, output of milk would increase on average by 0.9912 %. Both number of inseminations and workers variable had the highest output elasticity, were positively related to milk production and therefore their contribution to total milk productivity was dominant. A one percent increase in the number of inseminations and number of workers, ceteris paribus, lead to a 0.5778 and 0.1998 percent change in milk production, respectively. An increase in the scale of production through increase in the herd size, land, labour and concentrate use would increase milk productivity. However, the quantity of feed used was an insignificant factor in milk productivity. This may point to gaps in quality of fodder/feed used which were not effective in increasing productivity regardless of amounts used.

Table 4 Maximum likelihood estimates of the SFP function results

Ln Milk Yield (litres/year)	Coef.	Std. Err.	z	P>|z|
Ln Feed quantity	0.0155	0.0107	1.44	0.150
Ln Concentrates quantity	0.0523	0.0127	4.11	0.000***
Ln Cows	0.0523	0.0127	4.11	0.000***
Ln Land	0.0935	0.0276	3.38	0.001**
Ln Workers	0.1998	0.0539	3.70	0.000***
Ln Insemination number	0.5778	0.0873	6.62	0.000***
_cons	5.9389	0.3482	17.06	0.000
/lnsig2v	-1.2931	0.2795	0.00	-4.63
/lnsig2u	-2.2389	1.9373	-1.16	0.248
sigma_v	0.5238	0.0732		
sigma_u	0.3264	0.3162		
sigma2	0.3809	0.1348		
lambda	0.6231	0.3869		

***1 %, **5%, *10% level of significance

3.3.1 Distribution of technical efficiency scores

Table 5 Distribution of technical efficiency scores based on Cobb-Douglas specification per county

TE score	Kericho	Nakuru	Uasin Gishu	Total
<20 %	3 (2.04%)	2 (1.23%)	1 (1%)	6 (1.46%)
21 %-40%	35 (23.81%)	48 (29.45%)	25 (25%)	108 (26.34%)
41 %-60%	55 (37.41%)	58 (35.58%)	32 (32%)	145 (35.37%)
61 %-80%	24 (16.33%)	22 (13.5%)	24 (24%)	70 (17.07%)
81 %-100%	30 (20.41%)	33 (20.25%)	18 (18%)	81 (19.76%)
Total	147 (100%)	163 (100%)	100 (100%)	410 (100%)
Mean	0.6327			
Minimum	0.1601			
Maximum	0.8917			

The value in brackets stands for proportion of the sample under each of the categories.

Table 6 Distribution of technical efficiency scores based on Cobb-Douglas specification per dairy system

TE Score	Free grazing	Semi-intensive	Zero grazing	Total
<20 %	1 (0.49%)	0 (0%)	5 (7.25%)	6 (1.46%)
20 %-40%	50 (24.63%)	30 (21.74%)	28 (40.58%)	108 (26.34%)

41 %-60%	**67 (33%)**	**56 (40.58%)**	**22 (31.88%)**	**145 (35.37%)**
61%-80%	39 (19.21%)	26 (18.84%)	5 (7.25%)	70 (17.07%)
81 %-100%	46 (22.66%)	26 (18.84%)	9 (13.04%)	81 (19.76%)
Total	203 (100%)	138 (100%)	69 (100%)	410 (100%)
Mean	0.6989	0.6255	0.4085	
Minimum	0.1693	0.2185	0.3072	
Maximum	0.8422	0.8561	0.4192	

The results of the Stochastic Frontier Model showed the aggregate maximum and minimum technical efficiencies were between 0.8917 and 0.1601 respectively.

The farmer with the best practice had a technical efficiency of 0.8917 while the farmer with the worst practice had a technical efficiency of 0.1601 (table 6). The average technical efficiency was 0.6327 implying that farmers were able to obtain a little over 63 % of optimal output from a given mix of production inputs and production technology, hence they were 63.27% technically efficient. The results also mean that the farmers were producing milk below their respective frontier levels although they were above half of the frontier. This indicates that there is a scope for increasing technical efficiency by **36.73% in the short-run under the existing technology**. The average TE of the sampled farms was above average and could have been influenced by adoption of improved production practices as a result of exposure from projects such as KNPA and others and the drive to commercialize production for income generation as opposed to traditional goal of sustenance. This means that an average farm in the sample could in principle increase its level of **milk production by 36.73% using the current input quantities**.

The technical efficiency level of the most efficient farmer could achieve cost saving **of 29.01 %** (1- [63/89]) and similarly, the most technically inefficient farmer could realize cost saving of 82.04 % (1- [16/89]). The high variation in TE among the dairy farmers in the study area indicates there is great potential to increase milk production by improving technical efficiency of the farmers for increased incomes from dairying in the study areas.

3.4 Factors influencing technical efficiency

To identify sources of variations in technical efficiencies among dairy farmers, a censored regression Tobit model was applied where selected farm and farmer characteristics were regressed against the TE scores of each farmer. The results describing the influence of the selected variables and their direction of influence on TE as presented in table 7

Table 7 Determinants of technical efficiency on select production inputs for milk production

Variable	**Coef.**	**Std. Err.**	**T**	**P>t**
Education level	-0.0030	0.0050	-0.59	0.557
Primary occupation	-0.0008	0.0045	-0.17	0.864
Group membership	0.0041	0.0223	0.18	0.860
Gender	-0.0067	0.0216	-0.31	0.757
Dairy system	0.0515	0.0130	3.96	.000***
Tenancy	-0.0164	0.0073	-2.27	0.025**
Age	0.0006	0.0011	0.6	0.551

Household Size	-0.0036	0.0046	-0.78	0.437
Farming Experience	-0.0026	0.0014	-1.85	0.066*
_cons	0.5876	0.1196	4.91	0.000

***1%, **5%, *10% level of significance

Dairy production system had a positive effect on the technical efficiency of the dairy farmers and was significant at 1% level with a coefficient of 0.0515, this shows that as the dairy farmers intensify their dairy systems their level of technical efficiency increases by 0.0515. This can be attributed to the fact that in the extensive systems management and monitoring of the herd is poor compared to the intensive systems.

The coefficient for the tenancy was negative and significant at 5 % significance level. The negative effect of this coefficient implies that the ownership of land dictates the freedom that a farm gets on the land use. The farmers who own the land have freedom and full control of what and how to produce, but as the type of tenancy shifts from owned by the farmer to other forms of tenancy, holding other factors constant, the efficiency in dairy production decreases by 0.016.

Experience in dairy farming's effect on technical efficiency was negative and significant at 10 % level of significance. This implies that as years pass with continuous dairy farming the technical efficiency declines. This is attributed to the fact that **older dairy farmers** are relatively more **reluctant to take up appropriate technologies**, instead they prefer to hold to the traditional farming methods thus becoming more technically inefficient compared to their younger counterparts.

4. **Conclusions and Recommendations**

From the results it is noted that, the quantity of feed used was an insignificant factor in milk productivity and this indicates gaps in the quality of fodder. To increase dairy productivity, dairy farmers. increased the quantities of concentrate used. This turned out to be not only costly and unprofitable but made the enterprise less technically efficient. Thus, Initiatives that promote adoption, utilisation and commercialisation of fodder varieties that have a higher nutrient density and are more resilient to climate change than the commonly available feed resources would be a pliable pathway that would ensure all year-round feed supply, reduce quantity of forage used and need for concentrate feeding. Such fodder that can meet the nutritional requirements of improved dairy animals would reduce the cost of production and increase returns on investment. Furthermore, lowering concentrates is expected to avoid nutrition based metabolic disorders of the dairy cows which in turn result to positive outcomes regarding food quality and ecology (Leiber, 2014). Farmers therefore need access to key agricultural resources to increase the local availability of reliable climate-resilient forage for dairy cattle.

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